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THE HOT-PLATE IGNITION TEST: A PROPOSED NEW TEST FOR FIRE-RESISTANT CONVEYOR BELTS

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Canadian Explosive Atmospheres Laboratory

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THE HOT-PLATE IGNITION TEST: A PROPOSED NEW TEST FOR FIRE-RESISTANT CONVEYOR BELTS

by

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ABSTRACT

In this proposed test, 25 mm square samples of conveyor belting are placed on a hot stainless steel plate. The time to flaming ignition is measured for different plate temperatures and a curve plotted of ignition time versus temperature. The "ignition temperature" is defined as the temperature corresponding to the ten second ignition time read from the curve. Various parameters affecting the results are examined. Examples of both fire-resistant and non-fire-resistant belts are given.

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L'ESSAI D'INFLAMMATION SUR PLAQUE CHAUFFANTE: NOUVEL ESSAI PROPOSÉ AYANT POUR OBJET LES COURROIES TRANSPORTEUSES IGNIFUGÉES

par

K.J. Mintz*, J.A. Bossert** et M.S. Ralph***

RÉSUMÉ

L'essai proposé s'effectue de la façon suivante. Des échantillons de 25 mm par 25 mm de courroie transporteuse sont placés sur une plaque chauffante en acier inoxydable. On mesure le temps que la plaque met à provoquer l'inflammation des échantillons à diverses températures et l'on trace la courbe des temps d'inflammation en fonction des températures. La «température d'inflammation» est la température correspondant au point où la courbe croise la ligne de dix secondes. Divers paramètres influençant les résultats sont examinés. Des exemples sont donnés aussi bien pour des courroies transporteuses ignifugées que pour des courroies non ignifugées.

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INTRODUCTION

The tests currently used by Canadian Explosive Atmospheres Laboratory (CEAL) to certify fire-resistant conveyor belts for underground mines are a drum-friction test and a small-scale flame test (1). Previous work carried out at CEAL indicates that the latter test has two serious faults: (1) the scatter of data makes it possible to have false passes and false failures; (2) the correlation with the large-scale tests (the propane gallery) is poor. Because of the obvious difficulty in conducting large-scale tests, a small-scale test that would correlate with the propane gallery test would be extremely valuable. Although there are other small-scale tests available (Barthel Burner, Oxygen Index), they do not correlate well with the propane gallery test either. Consequently, it was decided to develop a new test based on the measurement of the surface ignition temperature. The criteria for the test are that it be quantitative (rather than just pass/fail), reproducible and inexpensive (so as to allow manufacturers and other interested parties to have their own testing facility). This report deals with the details of this test. Comparison of the test results with the large-scale test will be the subject of a subsequent report.

EXPERIMENTAL PROCEDURE

APPARATUS

Preliminary experiments were carried out using existing equipment available in CEAL: first, a steel channel heated by bunsen burners; second, a steel plate heated in a small muffle furnace. In both cases, pieces of belt were dropped onto the surface which had been heated to various temperatures, to determine the minimum temperature at which the sample ignited. The results obtained were sufficiently encouraging to justify purchase of better equipment and to make a more detailed study.

The requirements for the furnace were:

1. electronic controller,
2. maximum temperature of 1000°C or higher, and
3. large capacity, able to accommodate a steel plate of 305 mm square.

The particular furnace used was a Pyradia model 200.

The plate that is heated by the furnace must be made of a conducting material that does not scale at the maximum temperature. The plate must be of

sufficient mass that it does not cool down too rapidly when the source of heat is removed. A stainless steel plate type 310, of dimensions 305 x 305 x 25 mm was used. A 152 mm deep hole, 4 mm in diam was drilled in the edge of the plate to accommodate a thermocouple (3.2 mm diam), which was connected to a digital thermometer. The thermocouples were calibrated prior to use; their accuracy in this temperature range are ca. ±5°C.

An overall view of the apparatus is shown in Fig. 1. A close-up of the furnace when the plate has been heated to about 850°C is shown in Fig. 2. A burning sample of conveyor belt is shown in Fig. 3.

In the preliminary tests, the plate was pulled out from the muffle furnace before placing the sample on it. Because of the mass of the new plate, it was left inside the furnace during the test. The main objection to this approach is that the whole sample will be heated by radiation from the walls, not just the surface in contact with the plate. Fortunately, the walls cool down much more rapidly than the plate (see Fig. 4) and therefore do not heat the sample very much. (Note that Fig. 4 shows ΔT; the plate and walls were at the same temperature at time = 0.) We adopted the rule that the testing not commence until 5 min after the door has been opened, so as to allow for sufficient temperature difference between the walls and the plate.

The temperature distribution in the plate was determined by drilling three additional holes (Fig. 5) and monitoring at all four positions simultaneously using four thermocouples. After the furnace is turned off and its door opened, the temperature of the plate drops at a moderate rate, of the order of 0.1°C/s (Fig. 6). Note that the cooling curves of positions 1 and 2 are virtually identical, but position 3 cools significantly more rapidly due to being closer to the edge of the plate. Hence, to avoid any problems, samples should not be placed closer than 50 mm from the edges. Position 4 cools down slightly slower than position 1 even though it is only a few millimetres away, because the bottom surface of the plate cools slower than the top surface. By extrapolation of points 1 and 4 to the top surface of the plate, one can see that the temperature monitored at position 1, 6 mm below the surface, is a sufficiently accurate representation of the surface temperature, provided that the cooling rate is moderate.

After the furnace has been opened, the temperature of the plate is highest at the back and lowest at the front. Figure 7 shows this variation in temperature as a function of distance from the centre towards the front. The possible error in misplacing the sample by a couple of millimetres can be seen

to be much less than the accuracy of the thermocouples (ca. ±5°C). However, larger samples will have a substantial temperature gradient across them: for a 100 mm square sample, the temperature on one edge will be 20°C higher than the middle and 40°C higher than on the opposite edge.

The effect of a burning sample is shown in Fig. 8. A 25 mm square sample was placed on the centre of the plate and burst into flames almost instantaneously. It continued to burn for about 1 min. At position 1, located directly underneath the sample, the temperature began to rise 1 min after the sample began burning. This delay is caused by the relatively slow heat conduction in the s.s. plate. Position 2, located well away from the sample, is unaffected by the burning of the sample; its temperature can be regarded as what the temperature of the plate would be if no sample were placed on it. The temperature at position 1 approaches this temperature only very slowly. The temperature at position 4 is affected by the burning sample, but to much less an extent than the temperature at position 1. These data imply that the plate surface temperature is underestimated by the temperature of position 1 when a sample is burning and for a short period after. Hence, another sample should not be placed on the same spot for at least 3 min to allow time for the plate to equilibrate [if the sample is not removed immediately after it bursts into flame (the normal procedure), a longer time for equilibrium is required].

IGNITION TEMPERATURE

Without a much more elaborate apparatus than we used here, it is not possible to keep the plate temperature constant during a test of a sample, i.e., the plate and the surface follow the cooling curves discussed in the previous section. For example, if the sample is placed on the plate when it is 710°C and the sample bursts into flame at 700°C, the mean temperature the sample is exposed to is someplace in between. For simplicity, it is sufficiently accurate to take the mean value, in this example, 705°C.

There is not a sharp cut-off as the temperature is decreased between samples igniting and not igniting. The best way of presenting the data is to plot "ignition time" (i.e., the time that the sample remained on the hot surface before igniting) versus temperature (Fig. 9). At high temperatures, the ignition time is very short. As the temperature decreases, the ignition time increases fairly sharply, then plateaus, then increases sharply again. Clearly there is more than one mechanism occurring. At the higher tempera-

tures, only the surface of the sample is involved. At the plateau, the bulk of the material catches fire, not just the surface. The longer ignition time may be related to the heat conduction rate through the sample. The arrow on the lowest temperature point indicates that the sample did not catch fire but decomposed uneventfully. (Our experience indicates that if a sample has not ignited within 2 min exposure time to the hot plate, it is unlikely to do so no matter how long it is left on the plate.) These results indicate that the definition of an ignition temperature for this type of test is rather arbitrary. Since the purpose of the test is to estimate the surface ignition temperature, events occurring at long times can be safely ignored. To define an ignition temperature with some degree of precision, we must choose it to be on the steeply-rising portion of the curve. Hence, the "ignition temperature" is defined here, somewhat arbitrarily, as the temperature corresponding to an ignition time of 10 s.

In practice, random variation occurs which makes it impossible to obtain a reasonably accurate number from only one run. At least two runs are required to enable a smooth curve to be drawn. The "ignition temperature" is the intersection point of this curve with the 10 s line.

SAMPLE SIZE

To eliminate any effects from warp/weft cut directions, square samples are used. Ignition times-temperature curves are shown in Fig. 10 for various sizes of samples. (The individual experimental points are omitted for clarity.) Clearly, the ignition temperature is a strong function of the size, ranging from 805°C for the 10 mm square sample to 710°C for the 100 mm square sample.

The larger samples are exposed to a more non-uniform plate temperature. For the 150 mm square samples, one edge is exposed to a temperature ca. 30°C higher than the nominal (the centre) (Fig. 7). However, this factor alone cannot account for the observed differences in ignition times. The most important factor is that the larger samples (100 and 150 mm square and occasionally 50 mm square) warp when placed on the hot surface, trapping hot gases. Hence, the large samples may not provide a meaningful estimate of the surface ignition temperature.

The trend to higher ignition temperatures for the smaller samples may be due to the progressively greater loss of heat through the edges. In the range below 50 mm square, no clear choice of size can be made on the basis of

the most meaningful result. We chose 25 mm square to be the "standard" for convenience. An error of, say, 2 mm in cutting the sample will have negligible effect on the measured ingition temperature, whereas at smaller sizes, the necessity for accurate cutting becomes more important.

ACCURACY OF METHOD

There are several sources of error: thermocouple, placement of sample, surface effects of the plate and uncertainty in drawing the ignition time-temperature curve. Taking all these factors into account, the accuracy of the ignition temperature is estimated to be ca. ±10°C.

Most belts yield reasonably reproducible results (Fig. 9); a few have large scatter. The reason for this is unknown. Further work will be carried out on individual belts to try to identify the problem.

RESULTS AND DISCUSSION

Figure 11 shows the ignition time-temperature curves for several different conveyor belts, both rubber and PVC types. (The experimental points have again been omitted for clarity.) There is a variety of shapes for these curves. Note that a different choice of ignition times will change the order of ignition temperatures of some of the conveyor belts.

Belts A-E (Fig. 11) all contain fire-retardant materials and meet the current EMR specifications. Belts F and G are non-fire-resistant belts. As expected, the ignition temperatures of the latter are well below those of the fire-resistant belts. Although four of the fire-resistant belts are clustered fairly closely together, belt E is anomalously low. Although we are not at this time proposing a specific minimum value for the ignition temperature, based on concepts such as "best available technology", belt E would have to be rejected for certification if this test were made mandatory.

The results of EMR flame tests, oxygen index tests (2) and propane gallery tests (3) are given in Table 1, along with the ignition temperatures as read from Fig. 11. Although these data suggest some correlation amongst these methods, other work not presented here indicates that the relationships are more complex.

The hot-plate ignition test described in this report is deliberately non-sophisticated, using only off-the-shelf items. A smaller muffle furnace probably could be used, if desired, for reasons of cost and rate of heating.

The stainless steel plate should be of a sufficient mass to keep its cooling rate sufficiently slow. If other organizations decide to use this method, a round-robin study would be useful.

CONCLUSIONS

The hot-plate ignition test appears to be a relatively simple method of assessing one aspect of the flammability characteristics of conveyor belts. It may prove to be useful as a certification test for fire-resistant conveyor belts. Manufacturers may find it useful as a tool in developing new fire-resistant conveyor belts, or as a routine quality assurance test.

REFERENCES

1. Bossert, J.T. "Certification services for underground mining equipment and materials"; Division Report ERP/MRL 80-21(TR); 1980.

2. Mintz, K.J. "Procedure for oxygen index tests at the Canadian Explosive Atmospheres Laboratory"; Division Report ERP/MRL 83-46(TR); 1983.

3. National Coal Board Specification 158/1980, part 8.5.

Table 1 - Flammability tests on various conveyor belts.

	Hot plate ignition (°C)	Oxygen index	EMR flame test (*)	Propane gallery
A	810	31	--	Pass
B	800	32	Pass (10 s)	--
C	790	--	Pass (12 s)	Pass
D	770	32	Pass (2 s)	Pass
E	700	27	Pass (23 s)	Pass (marginal)
F	650	23	--	--
G	640	21	--	--

(*) mean time for flame to go out.

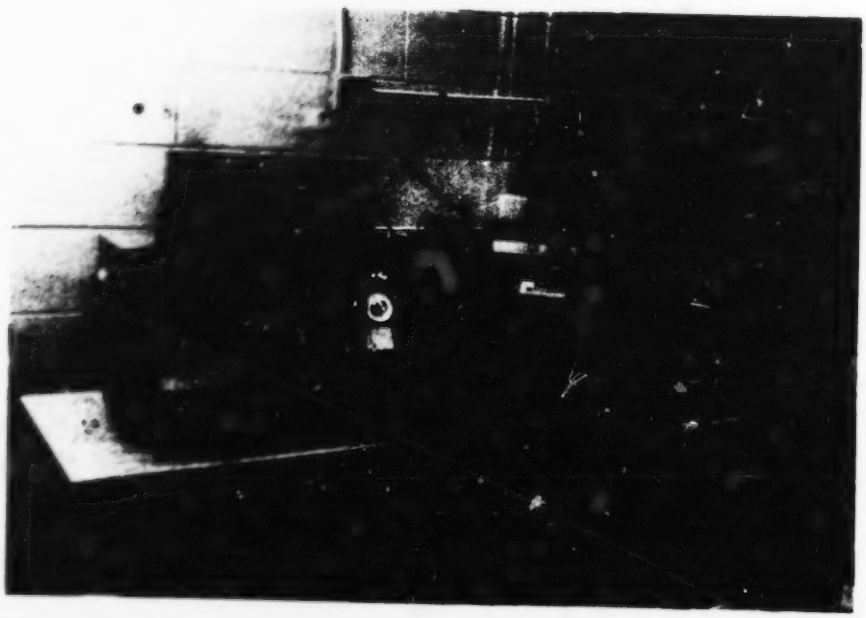

Fig. 1 - Overall view of the hot-plate ignition test apparatus.

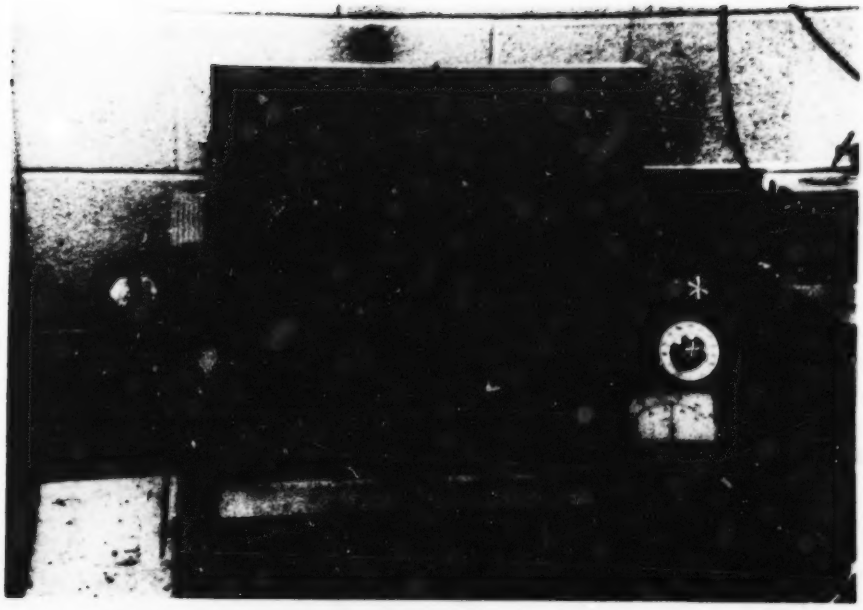

Fig. 2 - Close-up of the furnace.

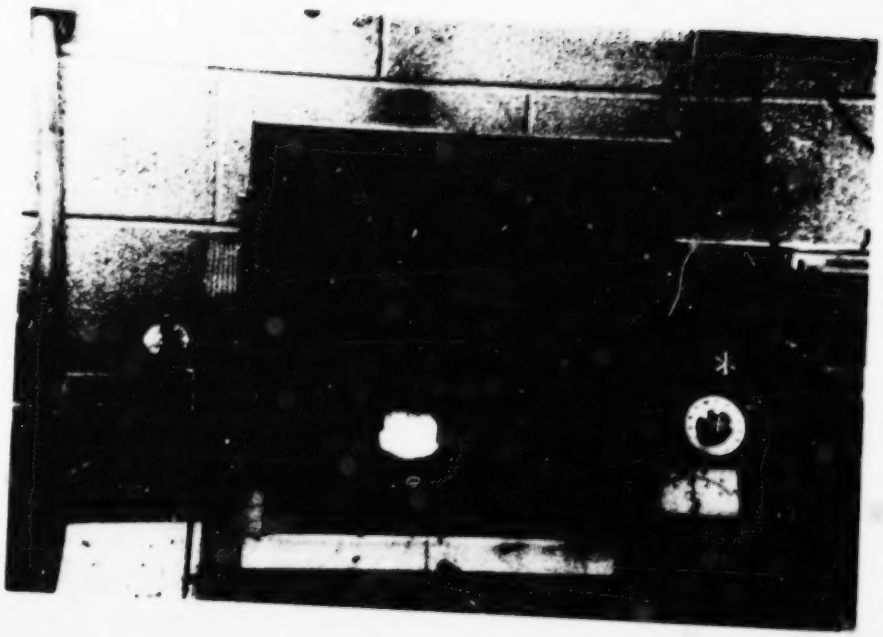

Fig. 3 - A sample of conveyor belt burning on the plate.

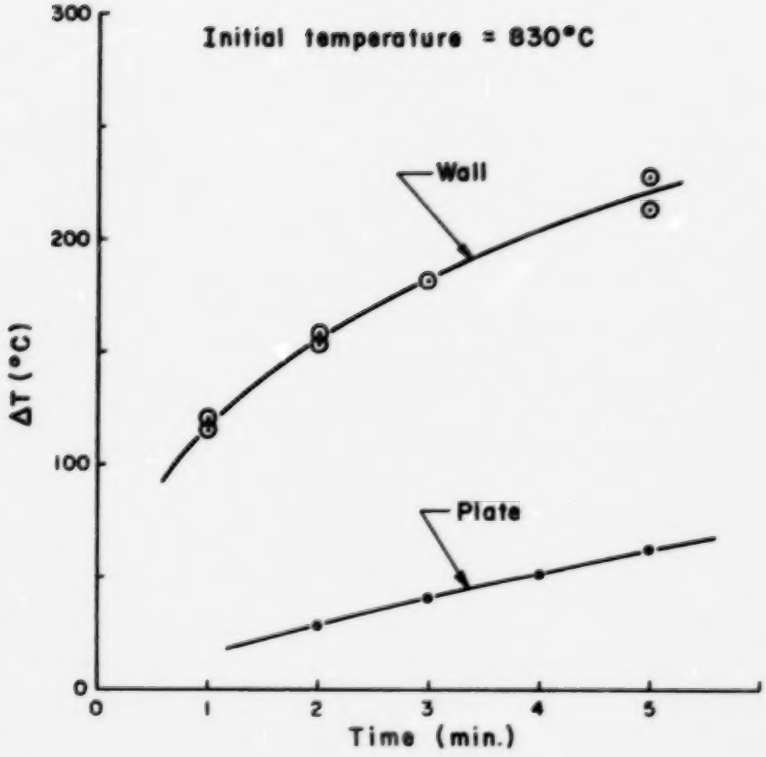

Fig. 4 - Temperature drop of plate and furnace wall.

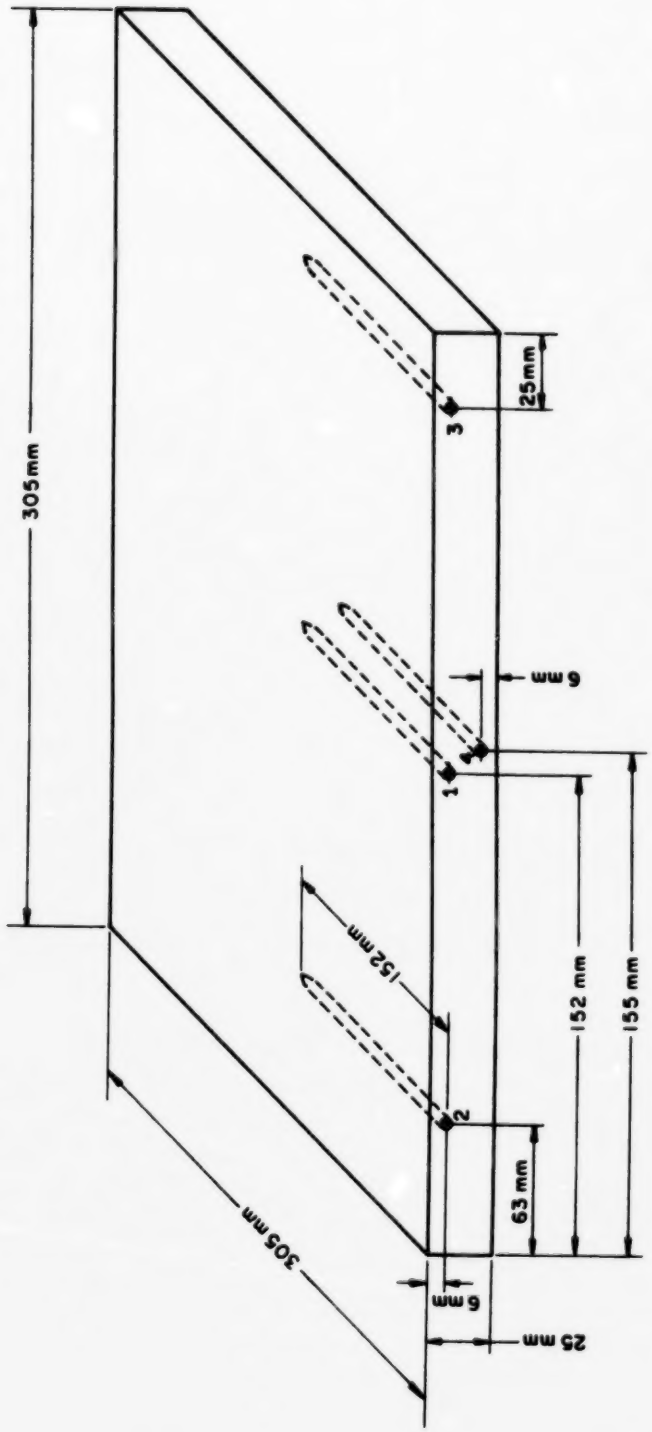

Fig. 5 - Position of thermocouple wells.

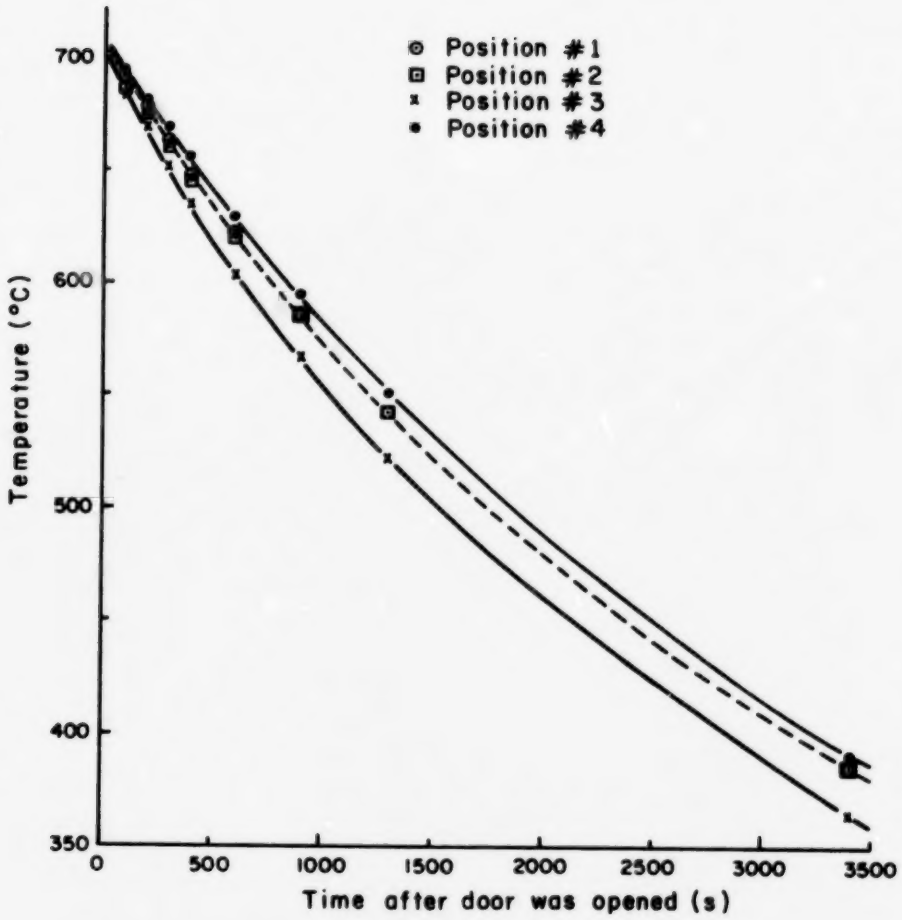

Fig. 6 - Cooling curves at four positions.

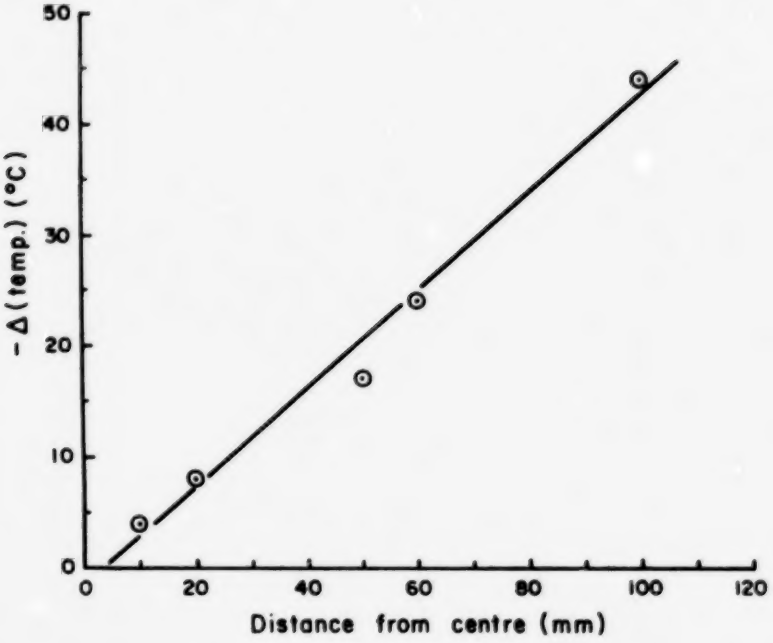

Fig. 7 - Temperature vs distance from centre of plate.

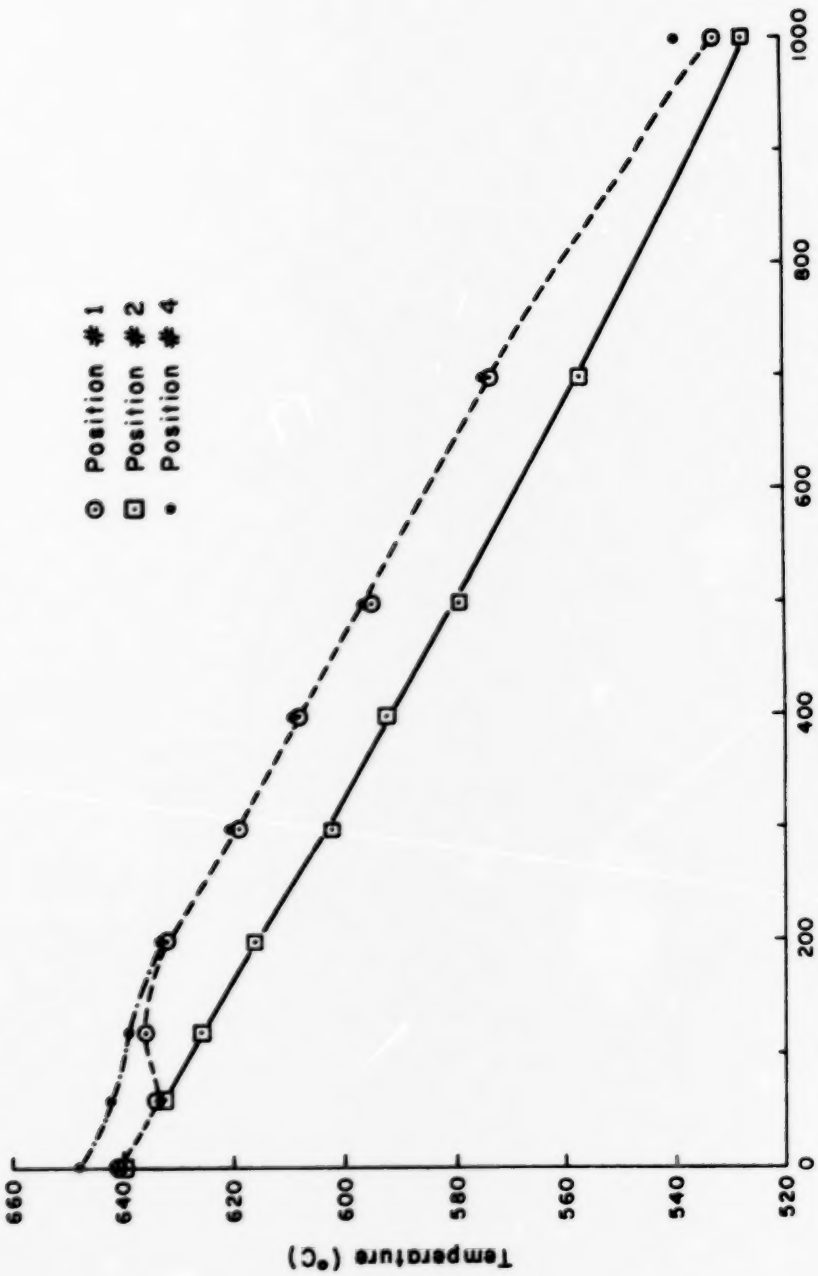

Fig. 8 - Cooling curves with burning sample.

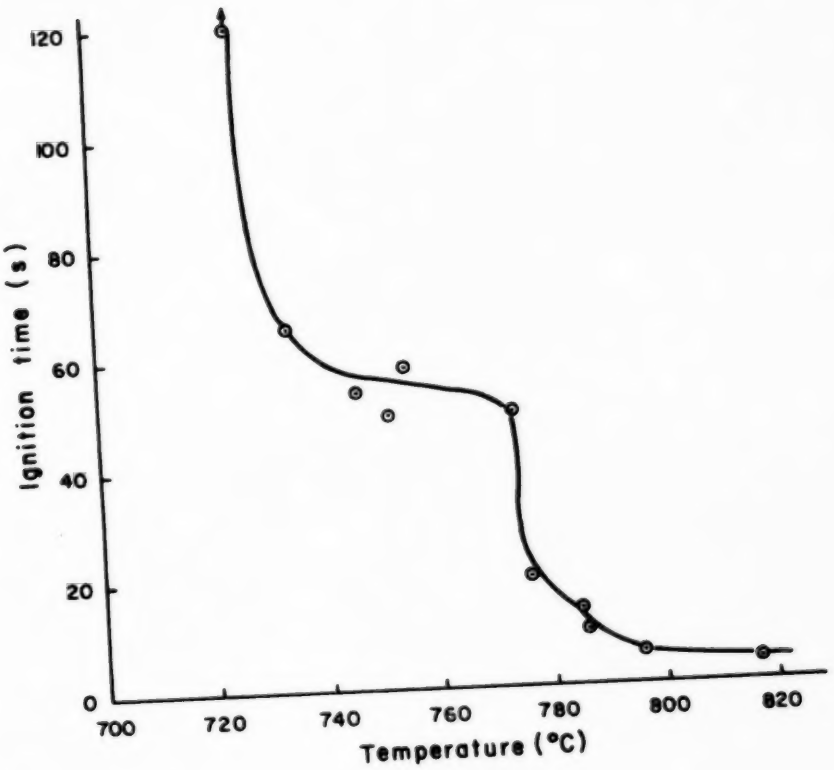

Fig. 9 - Ignition time vs temperature for a typical sample.

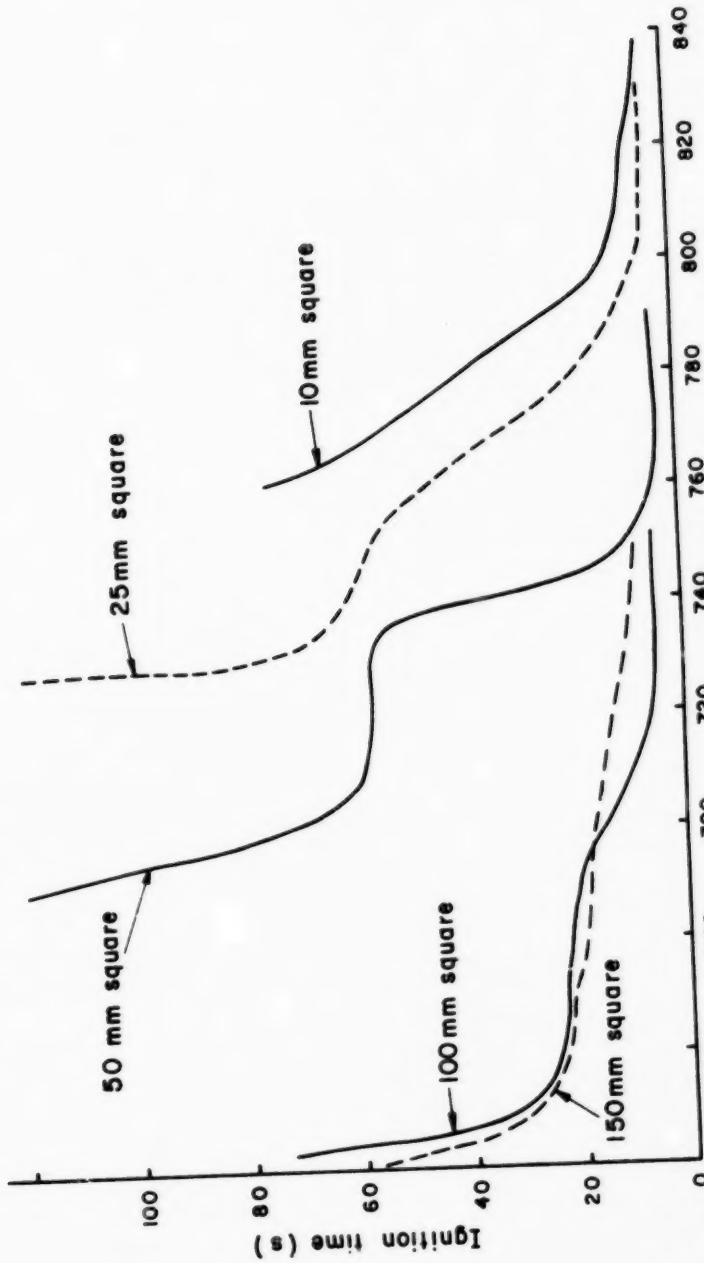

Fig. 10 - Effect on sample size.

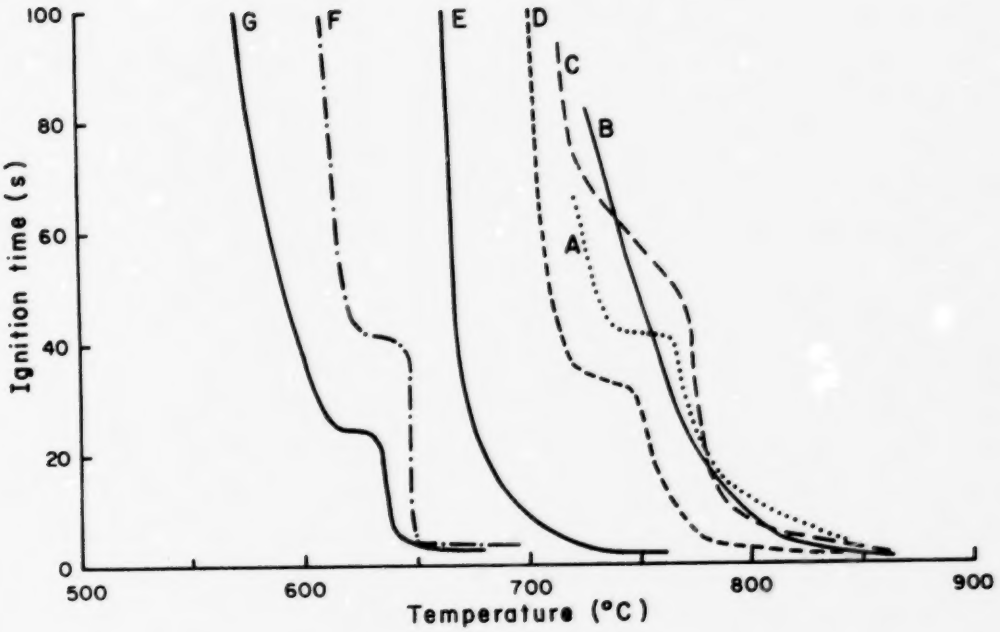

Fig. 11 - Ignition time-temperature curves for various conveyor belts.

APPENDIX

DETAILED PROCEDURE FOR HOT PLATE IGNITION TESTS

1. Heat muffle furnace to 100°C above the highest desired test temperature; allow sufficient time for the plate to equilibrate with the furnace (about 1 h for the Pyradia 200).

2. Turn off the furnace; open the furnace door; insert the thermocouple probe into the hole in the plate.

3. When the desired plate temperature has been reached, place the sample carefully onto the centre of the plate. At the same time start the timer. (A foot switch connected to the timer is useful.)

4. When the sample bursts into flames, stop the timer, note the temperature and remove the sample.

5. Scrape the debris off the plate; wait 3 min before placing another sample on the same spot.

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